HALCON Version 6.0

HALCON / C++

User's Manual

How to use the image analysis tool HALCON, Version 6.0, in your own C++ programs

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About This Manual

This manual describes the interface of HALCON to the programming language C++. It provides all necessary information to understand and use the provided C++ classes in your own programs. A set of example programs shows how to apply HALCON/C++ to solve typical image processing tasks.

The reader of this user manual should be familar with basic concepts of image analysis and the programming language C++.

The manual is divided into the following chapters:

- **Introducing HALCON/C++**
  A first example shows how easy image processing becomes using HALCON/C++.
- **The HALCON Parameter Classes**
  This chapter describes how to use the parameter classes of HALCON in your C++ program.
- **The Class `HWindow`**
  This chapter describes the HALCON/C++ class for graphics windows.
- **Structure of the Reference Manual**
  This chapter explains how to read the description of the operators in the HALCON/C++ reference manual.
- **Exception Handling**
  This chapter shows how to handle runtime errors in your C++ program.
- **Creating Applications Using HALCON/C++**
  This chapter explains how to compile and link C++ programs with HALCON/C++.
- **Typical Image Processing Problems**
  This chapter contains example programs for typical image processing tasks.

Release Notes

Please note the latest updates of this manual:

- 5^{th} **Edition, HALCON 6.0 (October 2000)**
  The manual has been restructured and revised slightly, especially the chapter “Creating Applications Using HALCON/C++”.

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Chapter 1

Introducing HALCON C++

HALCON/C++ is the interface of the image analysis system HALCON to the programming language C++. Together with the HALCON library, it allows to use the image processing power of HALCON inside C++ programs. HALCON provides operators covering a wide range of applications, e.g., factory automation, quality control, remote sensing, aerial image interpretation, medical image analysis, and surveillance tasks.

After pointing out additional sources of information about HALCON, we start with a first example application. The following chapters describe the use of the HALCON operators in C++ programs in more detail. Chapter 2 introduces the four different kinds of parameters of the HALCON operators and the corresponding C++ classes. We will explain how to pass tuples of numerical parameters to operators. Using this elegant way of tuples the above `SelectShape()` calls in the example program can be combined into one call in a really natural way. The class `HWindow` is used for the output of images and regions and is explained in chapter 3. Chapter 4 describes the structure of the reference manual and how to use it. The exception handling and return values of operators are discussed in chapter 5. Chapter 6 gives some remarks on the use of the HALCON library in your own application. Templates for solving typical image processing problems are given in chapter 7.

1.1 Additional Sources of Information

For further information you may consult the following manuals:

- **Getting Started with HALCON**
  An introduction to HALCON in general, including how to install and configure HALCON.
- **HDevelop User's Manual**
  An introduction to the graphical development environment of the HALCON system.
- **HALCON/C User's Manual**
  How to use the HALCON library in your C programs.
- **HALCON/COM User's Manual**
  How to use the HALCON library in your COM programs.
- **Extension Package Programmer's Manual**
  How to extend the HALCON system with your own operators.

- **Frame Grabber Integration Programmer's Manual**
  A guide on how to integrate a new frame grabber in the HALCON system. Note that in some cases you might define new operators (using the Extension Package Interface) instead of using the standard HALCON Frame Grabber Integration Interface in order to exploit specific hardware features of a frame grabber board.
- **HALCON/HDevelop, HALCON/C++, HALCON/C, HALCON/COM**
  The reference manuals for all HALCON operators (versions for HDevelop, C++, C, and COM).

All these manuals are available as PDF documents. The reference manuals are available as HTML documents as well. For the latest version of the manuals please check

```
http://www.mvtec.com/halcon/
```

1.2 A First Example

Let's start with a brief sample program before taking a closer look inside HALCON/C++.

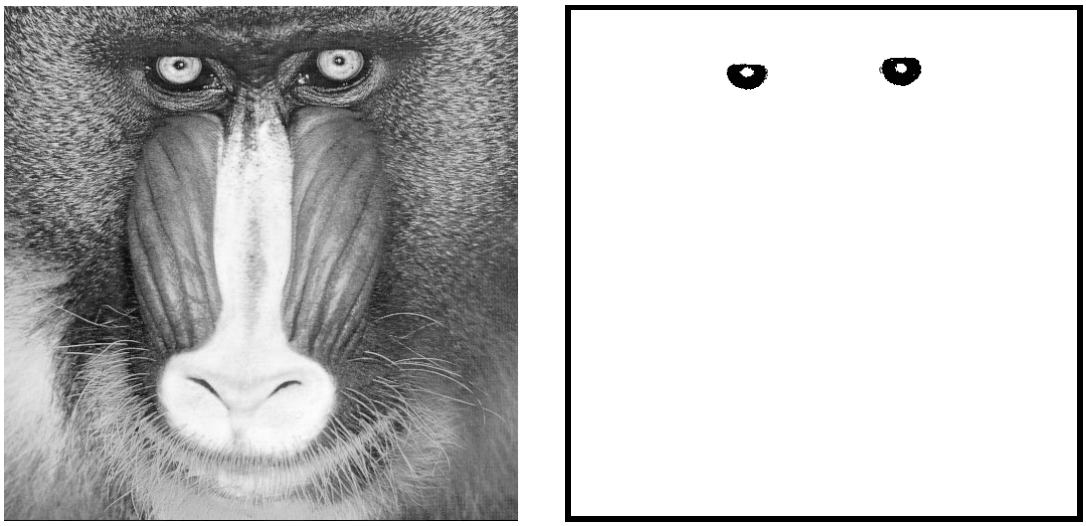

Figure 1.1: The left side shows the input image (a mandrill), and the right side shows the result of the image processing: the eyes of the monkey.

The input image is shown in figure 1.1 on the left side. The task is to find the eyes of the monkey by segmentation. The segmentation of the eyes is performed by the C++ program listed in figure 1.2, the result of the segmentation process is shown in figure 1.1 on the right side.

The program is more or less self-explanatory. However, the basic idea should be explained. First, all pixels of the input image are selected which have a gray value of at least 128, on the assumption that the image Mandrill is a byte image with a gray value range between 0 and 255. Secondly, the connected component analysis is performed. The result of the HALCON operator is an array of regions. Each region is isolated in the sense that it does not touch another region

```
#include "HalconCpp.h"

main()
{
  HImage  Mandrill("mandrill");        // read image from file mandrill
  HWindow w;                           // window with size equal to image

  Mandrill.Display(w);                 // display image in window
  w.Click();                           // wait for mouse click

  HRegion Bright = Mandrill >= 128;    // select all bright pixels
  HRegionArray Conn = Bright.Connection(); // get connected components

  // select regions with a size of at least 500 pixels
  HRegionArray Large = Conn.SelectShape("area","and",500,90000);

  // select the eyes out of the instance variable Large by using
  // the anisometry as region feature:
  HRegionArray Eyes = Large.SelectShape("anisometry","and",1,1.7);

  Eyes.Display(w);                     // display result image in window
  w.Click();                           // wait for mouse click
}
```

Figure 1.2: This program extract the eyes of the monkey.

according to the neighbourhood relationship. Among these regions those two are selected which correspond to the eyes of the monkey. This is done by using shape properties of the regions, the size and the anisometry.

This example shows how easy it is to integrate HALCON operators in any C++ program. Their use is very intuitive: You don't have to care about the underlying data structures and algorithms, you can ignore specific hardware requirements, if you consider e.g. input and output operators. HALCON handles the memory management efficiently and hides details from you, and provides an easy to use runtime system.

Chapter 2

The HALCON Parameter Classes

HALCON uses four different kinds of parameters for operators. Not all of them are used in every operator:

- Iconic input objects.
- Iconic output objects.
- Numerical input parameters.
- Numerical output parameters.

Input parameters are passed to an operator *by value*, output parameters are either a return value of an operator or passed to the caller by using the &-operator, i.e., *by reference*.

Most of the HALCON operators can handle more than one value for a parameter. In the case of iconic objects, arrays of the corresponding types (region, image, XLD) are provided and in the case of numerical parameters the tuple concept is used (see `class HTuple` in section 2.3.2). The operator `Connection()` in the example program in figure 1.2 returns an array of iconic objects: `RegionArray`. See the HALCON reference manual if you are unsure whether a parameter of an operator can have more than one value or not. Unfortunately, the standard C++ language doesn't provide polymorphic data structures for container classes. HALCON/C++ overcomes this by using the class `HTuple` for numerical parameters (see sections 2.3.2 and 2.3.4). This class implements the correct management of parameters, no matter if the type of the parameter is `int`, `float`, `string` or `array`.

2.1 Iconic Objects (`HObject`)

Image processing without images is hard to imagine. HALCON provides a data model which means more than handling simple image matrices. The base class of the HALCON/C++ class hierarchy is the (abstract) class `HObject` which manages entries in the database, i.e., the copying or releasing of objects. Entries in the database are represented by the class `Hobject` (see also section 2.2). The classes `HObject` and `Hobject` can contain all types of iconic objects. This has the advantage that important operators like the output (`Display()`) can be applied to all types in the same manner.

Three classes are derived from the root class `HObject`:

- Class `HImage` for handling images.
- Class `HRegion` for handling regions.
- Class `HXLD` for handling polygons.

These classes are described in detail below. Besides the member functions listed below, the classes contain further functions which are described in the HALCON reference manual.

2.1.1 Regions (`HRegion`)

A region is a set of coordinates in the image plane. Such a region does not need to be connected and it may contain holes. A region can be larger than the actual image format. Regions are represented by the so-called runlength coding in HALCON. The class `HRegion` represents a region in HALCON and contains the following member functions or *operators* in HALCON terms:

- `HRegion(void)`
  Default constructor. It creates an empty region, i.e., the area of this region is zero. Not all operators can handle the empty region as input, e.g. some shape property operators.
- `HRegion(const HDChord &line)`
  Constructing a region from a chord. A chord is a horizontal line.
- `HRegion(const HDPoint2D &point)`
  Constructing a region from a discrete 2-dimensional point.
- `HRegion(const HRectangle1 &rect)`
  Constructing a region from a rectangle parallel to the coordinate axis. The coordinates do not need to be discrete.
- `HRegion(const HRectangle2 &rect)`
  Constructing a region from an arbitrarily oriented rectangle. The coordinates do not need to be discrete.
- `HRegion(const HCircle &circle)`
  Constructing a region from a circle. The radius and center do not need to be discrete.
- `HRegion(const HEllipse &ellipse)`
  Constructing a region from an arbitrarily oriented ellipse. The radii and center do not need to be discrete.
- `HRegion(const char *file)`
  Constructing a region by reading the representation from file. This file can be generated by the member function `WriteRegion`.
- `HRegion(const HRegion &reg)`
  Copy constructor.
- `HRegion &operator = (const HRegion &reg)`
  Assignment operator.
- `~HRegion(void)`
  Destructor. In contrast to the primitive class (`Hobject`) this class handles the release of memory.

- `void Display(const HWindow &w) const`
  Output of the region in a window.
- `HRegion  operator * (double scale) const`
  Zooming the region by an arbitrary factor. The center of scaling is the origin $(0, 0)$.
- `HRegion  operator >> (double radius) const`
  `HRegion &operator >>= (double radius)`
  Minkowsky subtraction of the region with a circle of radius `radius`.
- `HRegion  operator << (double radius) const`
  `HRegion &operator <<= (double radius)`
  Minkowsky addition of the region with a circle of radius `radius`.
- `HRegion  operator + (const HDPoint2D &point) const`
  `HRegion &operator += (const HDPoint2D &point)`
  Translating the region by a 2-dimensional point.
- `HRegion &operator ++ (void)`
  Minkowsky addition of the region with a cross containing five points.
- `HRegion  operator + (const HRegion &reg) const`
  `HRegion &operator += (const HRegion &reg)`
  Minkowsky addition of the region with another region.
- `HRegion  operator - (const HRegion &reg) const`
  `HRegion &operator -= (const HRegion &reg)`
  Minkowsky subtraction of the region with another region.
- `HRegion &operator -- (void)`
  Minkowsky subtraction of the region with a cross containing five points.
- `HRegion  operator ~ (void) const`
  Complement of the region.
- `HRegion  operator ! (void) const`
  Transpose the region at the origin.
- `HRegion  operator & (const HRegion &reg) const`
  `HRegion &operator &= (const HRegion &reg)`
  Intersection of the region with another region.
- `HRegion  operator | (const HRegion &reg) const`
  `HRegion &operator |= (const HRegion &reg)`
  Union of the region with another region.
- `HRegion  operator / (const HRegion &reg) const`
  `HRegion &operator /= (const HRegion &reg)`
  Subtract another region from the region.
- `HBool operator == (const HRegion &reg) const`
  Boolean test if two regions are identical.
- `HBool operator >= (const HRegion &reg) const`
  `HBool operator > (const HRegion &reg) const`
  `HBool operator <= (const HRegion &reg) const`

`HBool operator < (const HRegion &reg) const`
Boolean test if another region is included in the region by using the subset of the corresponding coordinates.

- `double Phi(void) const`
  Orientation of the region by using the angle of the equivalent ellipse.
- `double Ra(void) const`
  Length of the major axis of the equivalent ellipse of the region.
- `double Rb(void) const`
  Length of the minor axis of the equivalent ellipse of the region.
- `long Area(void) const`
  Area of the region, i.e., number of pixels.
- `double X(void) const`
  `double Y(void) const`
  Center point of the region.
- `double Contlength(void) const`
  Length of the contour of the region, see `Contlength()`.
- `double Compactness(void) const`
  Compactness of the actual region, see `Compactness()`.
- `double Anisometry(void) const`
  `double Bulkiness(void) const`
  `double StructureFactor(void) const`
  Shape factors, see HALCON reference manual.
- `double M11(void) const`
  `double M20(void) const`
  `double M02(void) const`
  `double Ia(void) const`
  `double Ib(void) const`
  Moments of the region, see HALCON reference manual.
- `HRectangle1 SmallestRectangle1(void) const`
  Smallest surrounding rectangle parallel to the coordinate axis.
- `HBool In(const HDPoint2D &p) const`
  Boolean test if a point is inside a region.
- `HBool IsEmpty(void) const;`
  Boolean test if the region is empty, i.e., the area of the region is zero.

A program shows the power of the class `HRegion`, see figure 2.1.

First, an aerial image (`mreut.tiff`) is read from a file. All pixels with a gray value ≥ 190 are selected. This results in one region (`region`).

This region is transformed by the next steps: All holes in the region are filled (`FillUp()`) , small parts of the region are eliminated by two morphological operations, first an erosion, a kind of shrinking the region, followed by a dilation, a kind of enlarging the region. The last step is the zooming of the region. For that the region is first shifted by a translation vector $(-100, -150)$

```
#include "HalconCpp.h"
#include "iostream.h"

main ()
{
  HImage     image("mreut");          // Reading an aerial image
  HRegion    region = image >= 190;   // Calculating a threshold
  HWindow    w;                       // Display window
  w.SetColor("red");                  // Set color for regions
  region.Display(w);                  // Display the region
  HRegion    filled = region.FillUp() // Fill holes in region
  filled.Display(w);                  // Display the region
  // Opening: erosion followed by a dilation with a circle mask
  HRegion    open = (filled << 3.5) >> 3.5;
  w.SetColor("green");                // Set color for regions
  open.Display(w);                    // Display the region
  HDPoint2D  trans(-100,-150);        // Vector for translation
  HRegion    moved  = open + trans;   // Translation
  HRegion    zoomed = moved * 2.0;    // Zooming the region
}
```

Figure 2.1: Sample program for the application of the class `HRegion`.

Figure 2.2: On the left the input image (`mreut.tiff`), and on the right the region after the opening (`open`).

to the upper left corner and then zoomed by the factor two. figure 2.2 shows the input image and the result of the opening operation.

2.1.2 Region Arrays (`HRegionArray`)

The class `HRegionArray` serves as container class for regions. `HRegionArray` has the following member functions:

- `HRegionArray(void)`
  Constructor for an empty array (`Num()` is 0).
- `HRegionArray(const HRegion &reg)`
  Constructor with a single region.
- `HRegionArray(const HRegionArray &arr)`
  Copy constructor.
- `~HRegionArray(void)`
  Destructor.
- `HRegionArray &operator = (const HRegionArray &arr)`
  Assignment operator.
- `long Num(void)`
  Number of regions in the array, largest index is `Num()` -1.
- `HRegion const &operator [] (long index) const`
  Reading the element i of the array. The index is in the range $0 \ldots$ `Num()` -1.
- `HRegion &operator [] (long index)`
  Assigning a region to the element i of the array. The index `index` can be $\geq$ `Num()`.
- `HRegionArray operator () (long min, long max) const`
  Selecting a subset between the lower `min` and upper `max` index.
- `HRegionArray &Append(const HRegion &reg)`
  Appending another region to the region array.
- `HRegionArray &Append(const HRegionArray &reg)`
  Appending another region array to the region array.
- `void Display(const HWindow &w) const`
  Display the regions of the array in a window.
- `HRegionArray operator << (double radius) const`
  Applying the Minkowsky addition to all regions using a circular mask.
- `HRegionArray operator >> (double radius) const`
  Applying the Minkowsky subtraction to all regions using a circular mask.
- `HRegionArray operator + (const HRegion &reg) const`
  Applying the Minkowsky addition to all regions using another region as mask.
- `HRegionArray operator - (const HRegion &reg) const`
  Applying the Minkowsky subtraction to all regions using another region as mask.
- `HRegionArray operator ~ (void) const`
  Applying the complement operator to each region of the array.
- `HRegionArray operator & (const HRegionArray &reg) const`
  Intersection of each region of the actual array with the union of `reg`.
- `HRegionArray operator | (const HRegionArray &reg) const`
  Union of each region in the actual array with the union of `reg`.

- `HRegionArray operator / (const HRegionArray &reg) const`
  Difference of each region in the actual array with the union of `reg`.

Most HALCON operators accept `HRegionArray` as data structure for the input parameter, e.g. `union()`, `intersection()`, `difference()`, etc. The constructor instantiating the region array `HRegionArray` by a single region `HRegion` makes it possible to handle only one region. Without changing the data structure a `HRegionArray` can be used as input parameter even in the case of a single region.

Figure 2.3 shows a short example how to use the class `HRegionArray`.

```
#include "HalconCpp.h"
#include "iostream.h"

main ()
{
  HImage        image("control_unit");       // Reading an image from file
  // Segmentation by regiongrowing
  HRegionArray  regs = image.Regiongrowing(1,1,4,100);
  HWindow       w;                           // Display window
  w.SetColored(12);                          // Set colors for regions
  regs.Display(w);                           // Display the regions
  HRegionArray  rect;                        // New array
  for (long i = 0; i < regs.Num(); i++)      // For all regions in array
  { // Test size and shape of each region
    if ((regs[i].Area() > 1000) && (regs[i].Compactness() < 1.5))
      rect.Append(regs[i]);                  // If test true, append region
  }
  image.Display(w);                          // Display the image
  rect.Display(w);                           // Display resulting regions
}
```

Figure 2.3: Sample program for use of the class `HRegionArray`.

The first step is to read an image. In this case it shows a control unit in a manufacturing environment, see figure 2.4 on the left side. By applying a regiongrowing algorithm from the HALCON library the image is segmented into regions. Each region inside the resulting region array `regs` is now selected according to its size and its compactness. Each region of a size larger than 1000 pixels and of a compactness value smaller than 1.5 is appended to the region array `rect`. After the processing of the `for` loop only the regions showing on the right side of figure 2.4 are left.

2.1.3 Images (`HImage`)

Images contain at least one image matrix in conjuction with a region. This region defines the domain of the image. Various pixel types are supported. The class `HImage` is the root class for all derived image classes. By using the class `HImage` all different pixel types can be handled in a unique way (polymorphism). The class `HImage` is not virtual, thus it can be instantiated. It contains the following member functions:

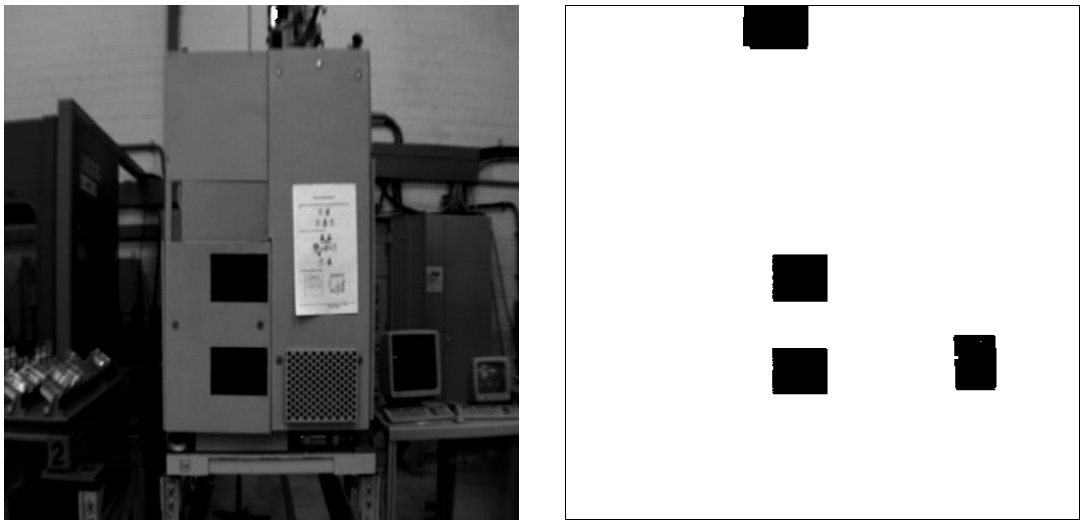

Figure 2.4: On the left side the input image (`control_unit.tiff`), and on the right side the selected rectangles.

- `HImage(void)`
  Default constructor, empty image.
- `HImage(const char *file)`
  Constructing an image by reading from a file, s. `ReadImage()`.
- `HImage(int width, int height, const char *type)`
  Constructing an image of a defined size and a specific pixel type, see `GenImageConst()`.
- `HImage(void *ptr, int width, int height, const char *type)`
  Constructing an image of a defined size and a specific pixel type by copying memory, see `GenImage1`.
- `HImage(const HImage &image)`
  Copy constructor.
- `virtual ~HImage(void)`
  Destructor.
- `HImage &operator = (const HImage &arr)`
  Assignment operator.
- `virtual const char *PixType(void) const`
  Return the pixel type of the image.
- `int Width(void) const`
  Return the width of the image.
- `int Height(void) const`
  Return the height of the image.
- `HPixVal GetPixVal(int x, int y) const`
  Access a pixel value via the (x, y) coordinates.
- `HPixVal GetPixVal(long k) const`
  Linear access of a pixel value.

- `virtual void SetPixVal(int x, int y, const HPixVal &val)`
  Set the pixel value via the (x, y) coordinates.
- `virtual void SetPixVal(long k, const HPixVal &val)`
  Set the pixel value by linear access.
- `virtual void Display(const HWindow &w) const`
  Display an image in a window.
- `HImage  operator & (const HRegion &reg) const`
  Reduce the domain of an image, see `ReduceDomain()`.
- `HImage  operator + (const HImage &add) const`
  Adding two images, see `AddImage()`.
- `HImage  operator - (const HImage &sub) const`
  Subtracting two images, see `SubImage()`.
- `HImage  operator * (const HImage &mult) const`
  Multiplication of two images, see `MultImage()`.
- `HImage  operator - (void) const`
  Inverting the values of the image see `Invert()`.
- `HImage  operator + (double add) const`
  `HImage  operator - (double sub) const`
  `HImage  operator * (double mult) const`
  `HImage  operator / (double div) const`
  Arithmetic operators, see `ScaleImage()`.
- `HRegion operator >= (const HImage &image) const`
  Selecting all pixel with gray values brighter than or equal to those of the input image, see `DynThreshold()`.
- `HRegion operator <= (const HImage &image) const`
  Selecting all pixel with gray values darker than or equal to those of the input image, see `DynThreshold()`.
- `HRegion operator >= (double thresh) const`
  Selecting all pixel with gray values brighter than or equal to a threshold, see `Threshold()`.
- `HRegion operator <= (double thresh) const`
  Selecting all pixel with gray values darker than or equal to a threshold, see `Threshold()`.
- `HRegion operator == (double thresh) const`
  Selecting all pixel with gray values equal to a threshold, see `Threshold()`.
- `HRegion operator != (double thresh) const`
  Selecting all pixel with gray values not equal to a threshold, see `Threshold()`.

Figure 2.5 gives an example of the use of the class `HImage`.

The example starts by reading a byte image from a file. The aim is to extract bright parts from the image. The used filter and the segmentation process itself is applied only in a pre-chosen part of the image in order to accelerate the runtime. This part is selected by drawing an arbitrary

```
#include "HalconCpp.h"
#include "iostream.h"

main ()
{
  HImage   image("mreut");                    // Aerial image
  HWindow  w;                                 // Output window
  image.Display(w);                           // Display image
  // Returning the size of the image
  cout << "width  = " << image.Width();
  cout << "height = " << image.Height() << endl;
  // Interactive drawing of a region by using the mouse
  HRegion  mask = w.DrawRegion();
  // Reduce the domain of the image to the mask
  HImage   reduced = image & mask;
  w.ClearWindow();                            // Clear the window
  reduced.Display(w);                         // Display the reduced image
  // Applying the mean filter in the reduced image
  HImage   mean = reduced.MeanImage(61,61);
  mean.Display(w);
  HRegion  reg = bild >= (mean + 3);
  reg.Display(w);
}
```

Figure 2.5: Sample program for the use of the class `HImage`.

Figure 2.6: On the left side the input image (`mreut.tiff`), and on the right side the segmented regions in the selected image domain.

region with the mouse. This region `mask` serves as input for reducing the domain of the original image (`&`-operator). The mean filter with a mask size of 61×61 is applied to the resulting region `reduced`. Bright pixels are selected by applying the `>=` operator. All pixels brighter than the filtered part of the image `reduced` $+3$ are selected. figure 2.6 shows the result of the sample program in figure 2.5.

2.1.4 Pixel Values (HPixVal)

The class HPixVal is used for accessing the pixel values of the class HImage. Gray values can be set and returned independent of their types:

- HPixVal(void)
  Default constructor.
- HPixVal(const HComplex &Val)
  Constructing a pixel value from a complex number.
- HPixVal(int Val)
  Constructing a pixel value from an integer (int).
- HPixVal(long Val)
  Constructing a pixel value from a long (long).
- HPixVal(HByte Val)
  Constructing a pixel value from a byte (byte).
- HPixVal(double Val)
  Constructing a pixel value from a double (double).
- HPixVal(const HPixVal &Val)
  Copy constructor.
- HPixVal &operator = (const HPixVal &grey)
  Assignment operator.
- operator HByte(void) const
  Converting a pixel value to byte $(0 \ldots 255)$.
- operator int(void) const
  Converting a pixel value to int.
- operator long(void) const
  Converting a pixel value to long.
- operator double(void) const
  Converting a pixel value to double.
- operator HComplex(void) const
  Converting a pixel value to Complex.

The handling of the class HPixVal is explained by an example in figure 2.7.

The program in figure 2.7 inverts the input image. The input image is a byte image. First, a copy is generated and the image size is determined. In the first run the pixels are accessed linearly. In the second run the pixel are accessed via the (x, y)-ccordinates.

2.1.5 Image Arrays (HImageArray)

The same way which was used to define arrays of regions is used to obtain arrays of images. The class is named HImageArray and contains the following member functions:

```
#include "HalconCpp.h"
#include <iostream.h>

main ()
{
  HImage  in("mreut");             // Aerial image
  HWindow w;                       // Output window
  in.Display(w);                   // Displaying the image
  HImage out = in;                 // Copying the image
  int  width  = out.Width();       // Width of the image
  int  height = out.Height();      // Height of the image
  long end    = width * height;    // Number of pixel of the image

  // 1. run: linear accessing
  for (long k = 0; k < end; k++) {
    int pix = in.GetPixVal(k);     // Reading the pixel
    out.SetPixVal(k,255-pix);      // Setting the pixel
  }
  // Displaying the transformation
  cout << "Transformed !" << endl;  out.Display(w);   w.Click();
  cout << "Original !"    << endl;  in.Display(w);    w.Click();

  // 2. run: accessing the image via the coordiantes (x,y)
  for (int y=0; y<height; y++) {
    for (int x=0; x<width; x++) {
      int pix = in.GetPixVal(x,y); // Reading the pixel
      out.SetPixVal(x,y,255-pix);  // Setting the pixel
    }
  }
  // Displaying the transformation
  cout << "Transformed !" << endl;  out.Display(w);   w.Click();
  cout << "Original !"    << endl;  in.Display(w);    w.Click();
}
```

Figure 2.7: Sample program for the use of the class `HPixVal`.

- `HImageArray(void)`
  Default constructor: empty array, no element.
- `HImageArray(const HImage &reg)`
  Constructing an image array from a single image.
- `HImageArray(const HImageArray &arr)`
  Copy constructor.
- `~HImageArray(void)`
  Destructor.
- `HImageArray &operator = (const HImageArray &arr)`
  Assignment operator.

- `long Num(void) const`
  Returning the number of elements in the array.
- `HImage const &operator [] (long index) const`
  Reading the element i of the array. The index is in the range $0 \ldots$ `Num()` $- 1$.
- `HImage &operator [] (long index)`
  Assigning a region to the element i of the array. The index `index` can be $\geq$ `Num()`.
- `HImageArray operator () (long min, long max)`
  Selecting a subset between the lower `min` and upper `max` index.
- `HImageArray &Append(const HImage &image)`
  Appending another image to the image array.
- `HImageArray &Append(const HImageArray &images)`
  Appending another image array to the image array.

2.1.6 Byte Images (`HByteImage`)

An important specialization of the class `HImage` is the class `HByteImage`. The range of the pixel values of the class `HByteImage` is between 0 and 255. This pixel type covers more than 90% of all applications in the field of image processing. The advantage of the class `HByteImage` in comparison to the class `HImage` is the simplified access to the pixel values. This is because the class `HPixVal` is not necessary. Besides the member functions of `HImage`, the class `HByteImage` contains the following extensions:

- `HByteImage(void)`
  Default constructor.
- `HByteImage(const char *file)`
  Constructing a byte image by reading a file.
- `HByteImage(int width, int height)`
  Constructing an empty byte image of a given size.
- `HByteImage(HByte *ptr, int width, int height)`
  Constructing a byte image by copying memory.
- `HByteImage(const HByteImage &image)`
  Copy constructor.
- `virtual ~HByteImage(void)`
  Destructor.
- `HByte &operator[] (long k)`
  Setting a pixel value by linear accessing.
- `HByte operator[] (long k) const`
  Reading a pixel value by linear accessing.
- `HByte &operator() (long k)`
  Setting a pixel value by linear accessing.

- `HByte operator() (long k) const`
  Reading a pixel value by linear accessing.
- `HByte &operator()(int x, int y)`
  Setting a pixel value by accessing it via (x, y) coordinates.
- `HByte operator()(int x, int y) const`
  Reading a pixel value by accessing it via (x, y) coordinates.
- `HByteImage operator & (int i)`
  Applying the logical “and”-operation on each pixel with `i`.
- `HByteImage operator << (int i)`
  Applying a left-shift on each pixel with `i`.
- `HByteImage operator >> (int i)`
  Applying a right-shift on each pixel with `i`.
- `HByteImage operator ~ (void)`
  Complement of each pixel.
- `HByteImage operator & (HByteImage &ima)`
  Pixel by pixel logical “and”-operation of two images.
- `HByteImage operator | (HByteImage &ima)`
  Pixel by pixel logical “or”-operation of two images.
- `HByteImage operator ^ (HByteImage &ima)`
  Pixel by pixel logical “xor”-operation of two images.

The advantage of the class `HByteImage` can be seen when accessing each pixel, see figure 2.8.

The class `HPixVal` is not necessary in this example. Furthermore the member functions `GetPixVal` and `SetPixVal` are not used. `HByteImage` allows the accessing of pixel values in a notation like in the programming language C. The result of the example in figure 2.8 is basically the same as in the example in figure 2.7. The program in figure 2.8 is shorter, easy to read, and has a better runtime performance.

2.2 Low-level Objects (`Hobject`)

For dealing with the entries in the database, i.e., with the low-level objects, HALCON/C++ provides the data type class `Hobject`. This data type allows you to access the internal HALCON data management. The class handles the keys of the database. The class `Hobject` serves as the basis for the class `HObject` and the derived classes. The class `Hobject` has the following member functions:

- `Hobject(void)`
  Default constructor.
- `Hobject(const Hobject &obj)`
  Copy constructor.
- `virtual ~Hobject(void)`
  Destructor.

```
#include "HalconCpp.h"
#include <iostream.h>

main ()
{
  HByteImage  in("mreut");         // Aerial image
  HWindow w;                       // Output window
  in.Display(w);                   // Displaying the image
  HImage out = in;                 // Copying the image
  int  width  = out.Width();       // Width of the image
  int  height = out.Height();      // Height of the image
  long end    = width * height;    // Number of pixel of the image

  // 1. run: linear accessing
  for (long k = 0; k < end; k++)
    out[k] = 255 - in[k];          // Reading and setting the pixel

  // Displaying the transformation
  cout << "Transformed !" << endl;  out.Display(w);   w.Click();
  cout << "Original !"    << endl;  in.Display(w);    w.Click();

  // // 2. run: accessing the image via the coordinates (x,y)
  for (int y=0; y<height; y++)
    for (int x=0; x<width; x++)
      out(x,y) = 255 - out(x,y);   // Reading and setting the pixel

  // Displaying the transformation
  cout << "Transformed !" << endl;  out.Display(w);   w.Click();
  cout << "Original !"    << endl;  in.Display(w);    w.Click();
}
```

Figure 2.8: Sample program for accessing a pixel value using the class `HByteImage`.

- `Hobject &operator = (const Hobject &obj)`
  Assignment operator.
- `void Clear(void)`
  Freeing the memory, but preserving the key.

2.3 Control Parameters

HALCON/C++ can handle different types of (alphanumerical) control parameters for HALCON operators:

- discrete numbers (`long`),
- floating point numbers (`double`), and
- strings (`char *`).

As already mentioned in the introduction to this chapter, using control parameter tuples in C++ isn't as elegant as using image object tuples (arrays). To circumvent the missing polymorphic classes in C++, it was necessary to introduce two different working modes into HALCON/C++: The *simple mode* and the *tuple mode*. If a tuple is necessary for at least one control parameter, the tuple mode has to be used for operator calls. In tuple mode, *all* control parameters of an operator must be passed as the type class `HTuple` (*Mixing of the two modes is not possible*). The tuple mode also has to be used if the number or type of values that a operators calculates isn't known beforehand.

The type of numerical input parameters is simply the class `HTuple`. This is because `HTuple` provides constructors for all basic data types.

Mentioning the control parameter types — How is the default type of control parameters determined for a given operator? Basically there are three ways:

1. The operator description in the HALCON reference manual,
2. the HALCON system operator `::get_param_info(...)` and
3. the description of the HALCON interface in the file `HProto.h`.

Sometimes the manuals mention more than one possible type. If only integers and floating point numbers are allowed for a parameter, values have to be passed as parameters of type `double`. For all other combinations of types, the tuple mode has to be used.

2.3.1 The Class `HCtrlVal`

Before considering the different ways of passing values to numerical parameters the classes `HTuple` and `HCtrlVal` are discribed. The class `HCtrlVal` serves as basis for the class `HTuple` and is normally hidden from the user because it is only used temporarily for type conversion:

- `HCtrlVal(void)`
  Default constructor.
- `HCtrlVal(long l)`
  Constructing a value from `long`.
- `HCtrlVal(int l)`
  Constructing a value from `int`.
- `HCtrlVal(double d)`
  Constructing a value from `double`.
- `HCtrlVal(const char *s)`
  Constructing a value from `char *`.
- `HCtrlVal(const HCtrlVal &v)`
  Copy constructor.
- `~HCtrlVal(void)`
  Destructor.

- `HCtrlVal& operator = (const HCtrlVal &v)`
  Assignment operator.
- `int ValType() const`
  Type of a value.
- `operator int(void) const`
  Conversion to `int`.
- `operator long(void) const`
  Conversion to `long`.
- `operator double(void) const`
  Conversion to `double`.
- `operator const char*(void) const`
  Conversion to `char *`.
- `double D() const`
  Accessing a value and conversion to `double`.
- `long L() const`
  Accessing a value and conversion to `long`.
- `int I() const`
  Accessing a value and conversion to `int`.
- `const char *S() const`
  Accessing a value and conversion to `char *`.
- `HCtrlVal operator + (const HCtrlVal &val) const`
  Adding two values.
- `HCtrlVal operator - (const HCtrlVal &val) const`
  Subtracting two values.
- `HCtrlVal operator * (const HCtrlVal &val) const`
  Multiplying two values.
- `HCtrlVal operator / (const HCtrlVal &val) const`
  Division of two values.

2.3.2 The Class `HTuple`

The class `HTuple` is built upon the class `HCtrlVal`. The class `HTuple` implements an array of dynamic length for instances of the class `HCtrlVal`. The default constructor constructs an empty array (`Num() == 0`). This array can dynamically be expanded via assignments. The memory management, i.e., reallocation, freeing, is also managed by the class. The index for accessing the array is in the range between 0 and `Num()` $- 1$.

The class `HTuple` plays an important role for the export of programs written in HDevelop to C++ code. The following member functions reflect only a small portion of the total. For further information please see the file `HTuple.h` which is included in the HALCON distribution.

- `HTuple(void)`
  Default constructor. Constructs an empty tuple.
- `HTuple(long l)`
  Constructing an array of length 1 from a discrete number `long` at index position 0.
- `HTuple(int l)`
  Constructing an array of length 1 from a discrete number converted to the internal type `long` at index position 0.
- `HTuple(HCoord c)`
  Constructing an array of length 1 from a coordinate at index position 0.
- `HTuple(double d)`
  Constructing an array of length 1 from a floating number `double` at index position 0.
- `HTuple(const char *s)`
  Constructing an array of length 1 from a string `char*` at index position 0.
- `HTuple(const HTuple &t)`
  Copying a tuple.
- `~HTuple()`
  Destructor.
- `HTuple &operator = (const HTuple& in)`
  Assignment operator.
- `HTuple Sum(void) const`
  Adding all elements in case they are numbers.
- `HCtrlVal &operator [] (int i)`
  Setting the $i-$th element.
- `HCtrlVal operator [] (int i) const`
  Reading the $i-$th element.
- `HTuple operator + (const HTuple &val) const`
  Adding two tuples element by element. The arrays have to be of the same size.
- `HTuple operator + (double &val) const`
  `HTuple operator + (int &val) const`
  Adding a number to each element of the tuple.
- `HTuple operator - (const HTuple &val) const`
  Subtracting two tuples element by element. The arrays have to be of the same size.
- `HTuple operator - (double &val) const`
  `HTuple operator - (int &val) const`
  Subtracting a number from each element of the tuple.
- `HTuple operator * (const HTuple &val) const`
  Multiplying two tuples element by element. The arrays have to be of the same size.
- `HTuple operator * (double &val) const`
  `HTuple operator * (int &val) const`
  Multiplying a number with each element of the tuple.

- `HTuple operator / (const HTuple &val) const`
  Division of two tuples element by element. The arrays have to be of the same size.
- `HTuple operator / (double &val) const`
  `HTuple operator / (int &val) const`
  Division of each element of the tuple by a number.
- `HTuple Concat(const HTuple &t) const`
  Concatenating two tuples.
- `extern ostream& operator<<(ostream &s, const HTuple &t)`
  Output of a tuple.
- `extern istream& operator>>(istream &s, HTuple &t)`
  Input of a tuple.

Figure 2.9 shows a short sample how to use tuples, i.e., the class `HTuple`.

```
#include "HalconCpp.h"
#include <iostream.h>

main ()
{
  HTuple  t;
  cout << t.Num() << '\n';             // The length of the tuple is 0
  t[0] = 0.815;                        // Assigning values to the tuple
  t[1] = 42;
  t[2] = "HAL";
  cout << t.Num() << '\n';             // The length of the tuple is 3
  cout << "HTuple = " << t << '\n';    // Using the << operator
  double d = t[0];                     // Accessing the tuple, if the
  long   l = t[1];                     // the types of the elements
  char  *s = t[2];                     // are known
  // Accessing the tuple, if the types of the elements are known
  printf("Values: %g %ld %s\n",t[0].D(),t[1].L(),t[2].S());
}
```

Figure 2.9: Sample for the use of the class `HTuple`.

The default constructor generates an empty tuple. By assigning values to the tuple it is automatically expanded, and the data types of the values are also stored. For accessing the tuple the normal array notation can be used. If the data type of a value is not known in advance, an explicit type conversion has to be performed, see figure 2.9.

2.3.3 The Simple Mode

By applying the so-called *simple mode* the HALCON operators can be used in your own C++ programs in a very natural way. In the simple mode, all numerical output values are variables having the following data types:

- `long` for discrete numbers,

- `double` for floating point numbers, and
- `char*` for strings.

The values are passed *by reference* using the &-operator. The data type string is a pointer to `char`. *The user has to take care of the memory allocation for the data type string in the case of output numerical values.*

2.3.4 The Tuple Mode

The tuple concept has been mentioned several times in this manual. A lot of HALCON operators have numerical parameters, and each parameter may have more than just one value. The class `HTuple` has been introduced in order to handle such parameters in a highly efficient way. Separate calls to one HALCON operator can be combined to just one call by using the tuple concept.

Besides the simple mode described above, HALCON/C++ offers also the so-called *tuple mode*. If a numerical output parameter uses a tuple of values, the tuple mode has to be applied. A mixture between simple and tuple mode is not possible. Furthermore the tuple mode has to be used if the *type* or the *number* of the returned values of a HALCON operator is not known in advance.

The syntax of tuple and simple mode are basically the same. The data type in the tuple mode is just `HTuple`, that's all.

If you are not interested in a certain value of a numerical output parameter you can use the anonymous variable "_" instead of passing a "dummy" tuple to that variable.

```
#include "HalconCpp.h"
#include "iostream.h"

main ()
{
  HTuple SysFlags,Info;                          // Tuple variables
  long  i;                                       // Loop variable

  ::get_system("?",&SysFlags);                   // Get system values

  for (i=0; i<SysFlags.Num(); i++) {
     ::get_system(SysFlags[i].S(),&Info);        // Get i-th Sysflag
     out << SysFlags[i] << "=" << Info << "\n";  // Print i-th Sysflag
   }
}
```

Figure 2.10: A sample program for using the tuple mode: output of the actual HALCON system state.

The sample program in figure 2.10 shows the use of a tuple. The program obtains information on the actual HALCON system state. The call `::get_system("?",&SysFlags)` gets all flags of the system and its current values. Because the number and the type of the numerical output parameter are not known in this case, the call has to be made in the tuple mode. The rest of the program is self-explanatory.

Chapter 3

The Class `HWindow`

Another important class for building programs with HALCON/C++ is the class `HWindow`. This class provides the management of HALCON windows in a very convenient way. The properties of HALCON windows can be easily changed, images, regions, and polygons can be displayed, etc. The class contains the following member functions:

- ```
  HWindow(int Row=0, int Column=0,
          int Width=-1, int Height=-1,
          int Father = 0, const char *Mode = "",
          const char *Host = "")
  ```
  Default constructor. The constructed window is opened.
- `~HWindow(void)`
  Destructor. This closes the window.
- `void Click(void) const`
  Waiting for a mouse click in the window.
- `HDPoint2D GetMbutton(int *button) const`
  Waiting for a mouse click in the window. It returns the current mouse position in the window and the number of the button that was pressed.
- `HDPoint2D GetMbutton(void) const`
  Waiting for a mouse click in the window. It returns the current mouse position in the window.
- `HDPoint2D GetMposition(int *button) const`
  Returning the mouse position and the pressed button without waiting for a mouse click.
- `HDPoint2D GetMposition(void) const`
  Returning the mouse position without waiting for a mouse click.
- `HCircle DrawCircle(void) const`
  Waiting for the user to draw a circle in the window.
- `HEllipse DrawEllipse(void) const`
  Waiting for the user to draw an ellipse in the window.
- `HRectangle1 DrawRectangle1(void) const`
  Waiting for the user to draw a rectangle parallel to the coordinate axis in the window.
  ```

- `HRectangle2 DrawRectangle2(void) const`
  Waiting for the user to draw a rectangle with an arbitrary orientation and size in the window.

Besides those elementary member functions, the class `HWindow` contains more operators which are explained in detail in the HALCON reference manual in the `Graphics` chapter.

Figure 3.1 shows the typical use of some member functions of the class `HWindow` and the different possibilities of displaying images and regions.

```
#include "HalconCpp.h"

main ()
{
  HImage  image("control_unit");     // Reading an image from a file
  HWindow w;                         // Opening an appropiate window
  image.Display(w);                  // Display the image
  w.SetLut("change2");               // Set a lookup table
  w.Click();                         // Waiting for a mouse click
  w.SetLut("default");               // Set the default lookup table
  w.SetPart(100,100,200,200);        // Set a part of the window
  image.Display(w);
  w.Click();
  // Adapting the part to the image again
  w.SetPart(0,0,bild.Height()-1,bild.Width()-1);
  image.Display(w);
  HRegionArray regs = image.Regiongrowing(1,1,4,100);
  w.SetDraw("margin");
  w.SetColored(6);
  regs.Display(w);
  w.Click();
  image.Display(w);
  w.SetShape("rectangle1");
  regs.Display(w);
}
```

Figure 3.1: Sample program for the use of the class `HWindow`.

The window is opened after reading the image from a file. This means, the window is scaled to the size of the image. The lookup table is changed afterwards, and the program waits for a mouse click in the window. A part of the image is zoomed now, and the program waits again for a mouse click in the window. By applying a region growing algorithm from the HALCON library (`regiongrowing()`) regions are generated and displayed in the window. Only the margin of the regions is displayed. It is displayed in 6 different colors in the window. The example ends with another way of displaying the shape of regions. The smallest rectangle parallel to the coordinate axes surrounding each region is displayed.

Chapter 4

Structure of the Reference Manual

The HALCON/C++ reference manual contains the complete description of all operators in the HALCON system in C++ syntax. This chapter explains how to read the description of the operators.

Most of the HALCON operators are used with more than one signature. The reasons for this are:

- Operators can be accessed either via the low-level data structure `Hobject` or via the high-level classes `HImage`, `HRegion`, `HImageArray`, and `HRegionArray`. The user can choose amongst them.
- Many of operators can have more than one value for a parameter, see Chapter 2. This holds for both iconic objects (images and regions) and for numerical parameters.

The user can choose between the different ways of calling an operator according to his needs.

The description in the reference manual reflects the low-level operators. This affects only the way of calling the operator, not the description of the functionality itself. The latter remains the same in any case.

If an operator is called using a low-level class, the return value of that operator is a state value of type `Herror`. The operator itself doesn't belong to a class hierarchy. Examples for such operators are:

```
Herror ::fetch_polygon (Hobject Region,
                        const HTuple& Tolerance,
                        HTuple* Rows, HTuple* Columns)

Herror ::mean_image    (Hobject Image, Hobject* MeanImage,
                        const HTuple& MaskWidth,
                        const HTuple& MaskHeight);

Herror ::area_center   (Hobject Regions, long* Area,
                        double* Row, double* Column)

Herror ::area_center   (Hobject Regions, HTuple* Area,
                        HTuple* Row, HTuple* Column)
```

The operator ::area_center can be called in simple and in tuple mode. If exactly one region is passed, then size, row, and column refer only to single value. If more than one region is passed, the numerical output parameter has to be of type HTuple because for *each* region a value for size, row, and column is passed.

The use of the member functions of the classes HRegion, HImage seems to be more complicated if you view it from the reference manual. The reason for this is that values are returned by the member functions and the operation itself is applied on the instance (this). This causes fewer parameters of the operator. However, the rules for the transformation are very simple:

1. The type of the *first* input parameter determines the class to which the operator belongs as a member function. This parameter vanishes from the set of parameters of this operator.
2. The first output parameter determines the return value of the operator. Again, this parameter vanishes from the set of parameters.

This is a very convenient way for calling operators from HALCON/C++. Consider this example:

```
HRegion      HImage::Threshold
             (const HTuple &MinGrey, const HTuple &MaxGrey) const

HRegionArray HImageArray::Threshold
             (const HTuple &MinGrey, const HTuple &MaxGrey) const

HImageArray  HImageArray::MeanImage
             (const HTuple &MaskWidth,
              const HTuple &MaskHeight) const
```

Calling the member functions looks like:

```
HImage  Image("control_unit");
HImage  Mean    = Image.MeanImage(11,11);
HRegion Region  = Mean.Threshold(0,120);
```

Compare the above approach with the use of the low-level data type HError:

```
Hobject Image, Mean, Region;
::read_image(&Image, "control_unit");
::mean_image(Image, &Mean, 11, 11);
::threshold(Mean, &Region, 0, 120);
::clear_obj(Image);
::clear_obj(Mean);
::clear_obj(Region);
```

The memory management has to be done manually by the user.

Chapter 5

Exception Handling

Two techniques are used in HALCON/C++ to handle runtime errors. The first creates an instance of the error and passes it to the exception handler. The second technique can be used when dealing with low-level operators; the return value corresponds to an error which can be analyzed subsequently.

5.1 The Class `HException`

If a runtime error occurs in HALCON/C++ an instance of the class `HException` is created. This instance contains all information concerning the error. After the generation the instance is passed to the exception handler. The exception handler can handle the error. The default exception handler returns an error message and terminates the program. Of course, you can implement and use your own exception handler (`InstallHandler`). The type of the exception handler is:

```
typedef void (*Handler)(const HException &except);
```

The parameter of the handler is the instance of the actual error. The declaration of the class `HException` is shown in figure 5.1. The important members of an error are:

`line`:	Number of the program line in which the error occurred
`file`:	Name of the file in which the error occurred
`proc`:	Name of the actual HALCON operator
`err`:	Number of the error, see below
`message`:	Error text

5.2 Return Values of low-level HALCON Operators

The return values of type `Herror` of the HALCON operators can be divided into two categories: messages `H_MSG_*` and errors `H_ERR_*`.

According to the parameter concept of the HALCON system four different messages can be returned:

```
class HException {
public:
  HException(const char *f, long l, const char *p, const char *m);
  HException(const char *f, long l, const char *p, Herror e);

  static Handler InstallHandler(Handler proc);

private:
  static Handler handler;                       // Exception-Handler
  long           line;                          // Line number
  const char     *file;                         // File name
  const char     *proc;                         // Name of the operator
  Herror         err;                           // Number of the error
  const char     *message;                      // Error text

  void PrintException(void);                    // Default exception handler
};
```

Figure 5.1: Part of the declaration of the class `HException`.

`H_MSG_TRUE`: the operator terminated without an error and the result value is the boolean value true.

`H_MSG_FALSE`: the operator terminated without an error and the result value is the boolean value false.

`H_MSG_VOID`: the operator terminated without an error and the result value void is returned.

`H_MSG_FAIL`: the operator terminated without an error and the result value means the operator has not performed successfully. This means, e.g. an operator is not responsible or a specific situation has not occurred.

In practice nearly all HALCON operators return the message `H_MSG_TRUE` if no error occurs.

An error in a HALCON operator normally leads to an exception handling. You can deactivate the exception handler by calling the operator

```
::set_check("~give_error");
```

In this case you can use the operator `::error_text`(). This operator returns for a given error number the corresponding error message. The operator

```
::set_check("give_error");
```

activates the HALCON internal exception handling again.

Chapter 6

Creating Applications Using HALCON C++

The HALCON distribution contains examples for building an application with HALCON/C++. Here is an overview of the HALCON/C++ (Windows NT notation of paths):

`include\cpp\HalconCpp.h`:
include file; contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ interface.

`bin\i586-nt4\halcon.lib,halcon.dll`:
The HALCON library (Windows NT or Windows 2000).

`bin\i586-nt4\halconcpp.lib,halconcpp.dll`:
The HALCON/C++ library (Windows NT or Windows 2000).

`bin\i586-nt4\parhalcon.lib,parhalcon.dll,parhalconcpp.lib,parhalconcpp.dll`:
The corresponding libraries of Parallel HALCON (Windows NT or Windows 2000).

`lib\%ARCHITECTURE%\libhalcon.so`:
The HALCON library (UNIX).

`lib\%ARCHITECTURE%\libhalconcpp.so`:
The HALCON/C++ library (UNIX).

`lib\%ARCHITECTURE%\libparhalcon.so,libparhalconcpp.so`:
The corresponding libraries of Parallel HALCON (UNIX).

`include\cpp\HProto.h`:
External function declarations.

`examples\cpp\example1-11.cpp`:
Example programs.

`examples\cpp\i586-nt4\example1-11\`:
Example projects to compile and link the example programs (Windows NT or Windows 2000).

`examples\cpp\makefile, make.%ARCHITECTURE%`:
Example makefiles to compile the example programs (UNIX).

`images\`:
Images used by the example programs.

`help\english.*`:
Files necessary for online information.

`doc\*`:
Various manuals (in subdirectories).

There are several example programs in the HALCON/C++ distribution. To experiment with these examples we recommend to create a private copy in your working directory.

`example1.c`	reads an image and demonstrates several graphics operators.
`example2.c`	demonstrates the direct pixel access.
`example3.c`	is an example for the usage of pixel iterators.
`example4.c`	demonstrates the edge detection with a sobel filter.
`example5.c`	solves a more complicated problem.
`example6.c`	is a very simple test program.
`example7.c`	demonstrates the generic pixel access.
`example8.c`	is an example for the usage of the tuple mode.
`example9.c`	introduces the XLD structure.
`example10.c`	demonstrates the usage of several contour structures.
`example11.c`	is another simple example for the usage uf tuples.

In the following, we briefly describe the relevant environment variables; see the manual **Getting Started with HALCON** for more information, especially about how to set these variables. Note, that under Windows NT and Windows 2000, all necessary variables are automatically set during the installation.

While a HALCON program is running, it accesses several files internally. To tell HALCON where to look for these files, the environment variable `HALCONROOT` has to be set. `HALCONROOT` points to the HALCON home directory. `HALCONROOT` is also used in the sample makefile.

The variable `ARCHITECTURE` describes the platform HALCON is used on. The following table gives an overview of the currently supported platforms and the corresponding values of `ARCHITECTURE`.

ARCHITECTURE	Operating System (Platform)
i586-nt4	Windows NT 4.0 or 2000 on Intel Pentium or compatible
i586-linux2.2	Linux 2.2 on Intel Pentium (or compatible)
sparc-sun-solaris7	Solaris 7 on Sparc Workstations
mips-sgi-irix6.5	IRIX 6.5 on SGI Workstations (Mips processors)
hppa1.1-hp-hpux10	HP-UX 10.x on Workstations (at least PA 1.1 processors)
alpha-dec-osf4.0	DIGITAL UNIX 4.0 [1] on Alpha processors

If user-defined packages are used, the environment variable HALCONEXTENSIONS has to be set. HALCON will look for possible extensions and their corresponding help files in the directories given in HALCONEXTENSIONS.

Two things are important in connection with the example programs: The default directory for the HALCON operator read_image(...) to look for images is %HALCONROOT%\images. If the images reside in different directories, the appropriate path must be set in read_image(...) or the default image directory must be changed, using set_system("image_dir","..."). This is also possible with the environment variable HALCONIMAGES. It has to be set before starting the program.

The second remark concerns the output terminal under UNIX. In the example programs, no host name is passed to open_window(...). Therefore, the window is opened on the machine that is specified in the environment variable DISPLAY. If output on a different terminal is desired, this can be done either directly in ::open_window(...,"hostname",...) or by specifying a host name in DISPLAY.

In order to link and run applications under UNIX, you have to include the HALCON library path $HALCONROOT/lib/$ARCHITECTURE in the system variable SHLIB_PATH on a HP-UX architecture, and in the system variable LD_LIBRARY_PATH on all other UNIX architectures, respectively.

6.1 Creating Applications Under Windows NT/ 2000

Your own C++ programs that use HALCON operators must include the file HalconCpp.h, which contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ interface. Do this by adding the command

```
#include "HalconCpp.h"
```

near the top of your C++ file. In order to create an application you must link the library halconcpp.lib/.dll to your program.

The example projects show the necessary Visual C++ settings. For the examples the project should be of the WIN 32 ConsoleApplication type. Please note that the Visual C++ compiler implicitly calls “Update all dependencies” if a new file is added to a project. Since HALCON runs under UNIX as well as under Windows NT, the include file HalconCpp.h includes several UNIX-specific headers as well if included under UNIX. Since they don’t exist under NT, and

[1] now called Tru64 UNIX

the Visual C++ compiler is dumb enough to ignore the operating-system-specific cases in the include files, you will get a number of warning messages about missing header files. These can safely be ignored.

Please assure that the stacksize is sufficient. Some sophisticated image processing problems require up to 6 MB stacksize, so make sure to set the settings of your compiler accordingly (See your compiler manual for additional information on this topic).

If you want to use Parallel HALCON, you have to link the libraries `parhalcon.lib/.dll` and `parhalconcpp.lib/.dll` instead of `halcon.lib/.dll` and `halconcpp.lib/.dll` in your project.

6.2 Creating Applications Under UNIX

Your own C++ programs that use HALCON operators must include the file `HalconCpp.h`, which contains all user-relevant definitions of the HALCON system and the declarations necessary for the C++ interface. Do this by adding the command

```
#include "HalconCpp.h"
```

near the top of your C++ file. Using this syntax, the compiler looks for `HalconCpp.h` in the current directory only. Alternatively you can tell the compiler where to find the file, giving it the `-I<pathname>` command line flag to denote the include file directory.

To create an application, you have to link two libraries to your program: The library `libhalconcpp.so` contains the various components of the HALCON/C++ interface. `libhalcon.so` is the HALCON library.

Please take a look at the example makefiles for suitable settings. If you call `make` without further arguments, the example application `example1` will be created. To create the other example applications (e.g., `example2`), call

```
make TEST_PROG=example2
```

You can use the example makefiles not only to compile and link the example programs but also your own programs (called e.g. `test.cpp`) by calling

```
make TEST_PROG=test
```

You can link the program to the Parallel HALCON libraries by calling

```
make parallel TEST_PROG=test
```

Chapter 7

Typical Image Processing Problems

This chapter shows the power the HALCON system offers to find solutions for image processing problems. Some typical problems are introduced together with sample solutions.

7.1 Thresholding an Image

Some of the most common sequences of HALCON operators may look like the following one:

```
HByteImage   Image("file_xyz");
HRegion      Threshold        = Image.Threshold(0,120);
HRegionArray ConnectedRegions = Threshold.Connection();
HRegionArray ResultingRegions =
               ConnectedRegions.SelectShape("area","and",10,100000);
```

This short program performs the following:

- All pixels are selected with gray values between the range 0 and 120.
- A connected component analysis is performed.
- Only regions with a size of at least 10 pixel are selected. This step can be considered as a step to remove some of the noise from the image.

7.2 Edge Detection

For the detection of edges the following sequence of HALCON/C++ operators can be applied:

```
HByteImage Image("file_xyz");
HByteImage Sobel = Image.SobelAmp("sum_abs",3);
HRegion    Max   = Sobel.Threshold(30,255);
HRegion    Edges = Max.Skeleton();
```

A brief explanation:

- Before applying the sobel operator it might be useful first to apply a low-pass filter to the image in order to suppress noise.
- Besides the sobel operator you can also use filters like `EdgesImage`, `Prewitt`, `Robinson`, `Kirsch`, `Roberts`, `BandpassImage`, or `Laplace`.
- The threshold (in our case 30) must be selected appropiately depending on data.
- The resulting regions are thinned by a `Skeleton()` operator. This leads to regions with a pixel width of 1.

7.3 Dynamic Threshold

Another way to detect edges is e.g. the following sequence:

```
HByteImage Image("file_xyz");
HByteImage Mean      = Image.MeanImage(11,11);
HRegion    Threshold = Image.DynThreshold(Mean,5,"light");
```

Again some remarks:

- The size of the filter mask (in our case 11×11) is correlated with the size of the objects which have to be found in the image. In fact, the sizes are proportional.
- The dynamic threshold selects the pixels with a positive gray value difference of more than 5 (brighter) than the local environment (mask 11×11).

7.4 Texture Transformation

Texture transformation is useful in order to obtain specific frequency bands in an image. Thus, a texture filter detects specific structures in an image. In the following case this structure depends on the chosen filter; 16 are available for the operator `LawsByte()`.

```
HByteImage Image("file_xyz");
HByteImage TT   = Image.LawsByte(Image,"ee",2,5);
HByteImage Mean = TT.MeanImage(71,71);
HRegion    Reg  = Mean.Threshold(30,255);
```

- The mean filter `MeanImage()` is applied with a large mask size in order to smooth the “frequency” image.
- You can also apply several texture transformations and combine the results by using the operators `AddImage()` and `MultImage()`.

7.5 Eliminating Small Objects

The following morphological operator eliminates small objects and smoothes the contours of regions.

```
           ...
::segmentation(Image,&Seg);
HCircle Circle(100,100,3.5);
HRegionArray Res = Seg.Opening(Circle);
```

- The term `::segmentation()` is an arbitrary segmentation operator that results in an array of regions (`Seg`).
- The size of the mask (in this case the radius is 3.5) determines the size of the resulting objects.
- You can choose an arbitrary mask shape.

7.6 Selecting Oriented Objects

Another application of morphological operators is the selection of objects having a certain orientation:

```
         ...
::segmentation(Image,&Seg);
HRectangle2 Rect(100,100,0.5,21,2);
HRegionArray Res = Seg.Opening(Rect);
```

- Again, `::segmentation()` leads to an array of regions (`Seg`).
- The width and height of the rectangle determine the minimum size of the resulting regions.
- The orientation of the rectangle determines the orientation of the regions.
- Lines with the same orientation as `Rect` are kept.

7.7 Smoothing Contours

The last example in this user's manual deals again with morphological operators. Often the margins of contours have to be smoothed for further processing, e.g. fitting lines to a contour. Or small holes inside a region have to be filled:

```
         ...
::segmentation(Image,&Seg);
HCircle Circle(100,100,3.5);
HRegionArray Res = Seg.Closing(Circle);
```

- Again, `::segmentation()` leads to an array of regions (`Seg`).
- For smoothing the contour a circle mask is recommended.
- The size of the mask determines how much the contour is smoothed.

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